DOCUMENT RESUME

ED 441 018 TM 030 816

AUTHOR Thakkar, U.; Carragher, B.; Carroll, L.; Conway, C.; Grosser, B.; Kisseberth, N.; Potter, C. S.; Robinson, S.; Sinn-Hanlon, J.; Stone, D.; Weber, D.

TITLE Formative Evaluation of Bugscope: A Sustainable World Wide Laboratory for K-12.

PUB DATE 2000-04-00

NOTE 37p.; Paper presented at the Annual Meeting of the American Educational Research Association (New Orleans, LA, April 24-28, 2000).

PUB TYPE Reports - Evaluative (142) -- Speeches/Meeting Papers (150)

EDRS PRICE EDRS Price MF01 Plus Postage. PC Not Available from EDRS.

DESCRIPTORS *Biology; *Computer Assisted Instruction; Educational Technology; Elementary Secondary Education; *Instructional Effectiveness; *Science Education; Teaching Methods

ABSTRACT

Bugscope is an emerging educational technology project that allows students and teachers across grades K-12 to study insects and other arthropods through remote access and control of an environmental scanning electron microscope from their classroom computers. Teachers and students in 33 schools from 18 states and the U.S. Virgin Islands were selected to participate in the first year of the project. This paper provides an overview and formative evaluation of the project in order to assess its current impact and to guide further development. Evaluation data were received from 3 surveys of 36 teachers selected for the evaluation. Only 29 teachers completed all 3 surveys, and only 2 did not submit any survey responses. About 661 students participated in Bugscope classroom sessions. Results from the first year indicate that Bugscope was successful. Students and teachers had the opportunity to mail in specimens of insects and other arthropods and then study the high magnification images on the microscope, which they controlled remotely from their school computers at a scheduled place and time. Teachers were able to integrate Bugscope into their curricula, and both students and teachers thought the sessions enhanced learning. (Contains 7 figures and 25 references.) (SLD)

Reproductions supplied by EDRS are the best that can be made
from the original document.

ED 441 018

Formative Evaluation of Bugscope: A Sustainable World Wide Laboratory for K-12

U. Thakkar,[1] B. Carragher,[†] L. Carroll,[*] C. Conway,[‡] B. Grosser,[†] N. Kisseberth,[†]
C. S. Potter,[†] S. Robinson,[†] J. Sinn-Hanlon,[†] D. Stone,[‡] and D. Weber[†]

National Center for Supercomputing Applications
Graduate School of Library and Information Science
Department of Curriculum and Instruction
[†]Beckman Institute for Advanced Science and Technology
[*]Department of Entomology
[‡]University Laboratory High School
University of Illinois at Urbana-Champaign
Urbana, IL 61801

Paper prepared for the Annual Meeting of American Educational Research Association,
Special Interest Group on Advanced Technologies for Learning,
New Orleans, Louisiana, April 24-28, 2000.[2]

Abstract

Bugscope is an emerging educational technology project that allows students and teachers across K-12 to study insects and other arthropods through remote access and control of an environmental scanning electron microscope from their classroom computers. Teachers and students in 33 schools from 18 states in the United States and the US Virgin Islands were selected to participate during the first year of the project. This paper provides an overview and a formative evaluation of the project in order to assess its current impact and to guide further development.

TM030816

[1] To whom all correspondence should be addressed.
[2] The title of the abstract submitted for review in August, 1999, was "Preliminary Evaluations of Bugscope: A Sustainable World Wide Laboratory for K-12."

BEST COPY AVAILABLE

> What if expensive, but important scientific instruments such as the Hubble Telescope, electron microscopes, or even remote sensing satellites were on the network, and students could queue up requests for their use? This is not a farfetched scenario.
>
> Soloway (1994, p. 16)

> The students saw an intimate view of the insect that could not have been seen through a light microscope in the classroom. They saw the raw structure of an insect and began to question that structure's use. It gave the students a basic look at a real phenomenon of nature and caused them to question what it was or for what it was used. This is a basis of the scientific method and a "hook" to catch the interest of the student.
>
> High School Teacher (9th grade)

Introduction

Learning, teaching, and research activities in K-12 classrooms are beginning to change as schools respond to current efforts to reform science, mathematics, and technology education (e.g., Linn, 1992) and as they gain Internet connectivity. An example of these changes is Bugscope,[3] a new educational technology project in the World Wide Laboratory (WWL) at the Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana-Champaign (Potter, 1998).

The WWL provides control of scientific imaging instruments using the Internet. The WWL approach has three advantages. First, it provides researchers at all levels from any place and at any time access to the latest scientific instruments without having to travel or invest in such hardware. Second, it provides researchers with an opportunity for collaboration and consultation with other researchers anywhere in the world, thus creating a network of distributed expertise. Third, it provides innovative opportunities for education and training (Carragher and Potter, 1998, p. 1).

Bugscope is an educational innovation of the WWL for K-12 (see Figure 1). It allows students and teachers across K-12 to study insects and other arthropods through remote access and control of an environmental scanning electron microscope (ESEM). Classrooms supply their insect specimens in advance. The specimens are then prepared and inserted into the microscope by the project's operations team, comprised primarily of high school and undergraduate students, who are assisted by a professional electron microscopist. Then, using a standard World Wide Web (web) browser from their classroom computers, students and teachers gain access to and remotely operate the microscope to examine their specimens. Each classroom is initially allowed a single opportunity to access the microscope from their school computers at a pre-arranged date and time. The primary goal of Bugscope is to demonstrate that relatively low cost, sustainable access to the microscope can be made available to K-12 classrooms

[3] http://bugscope.beckman.uiuc.edu

nationwide, at a rate of 100 classrooms per year, using less than three hours of instrument time per week, and using minimal staff resources.

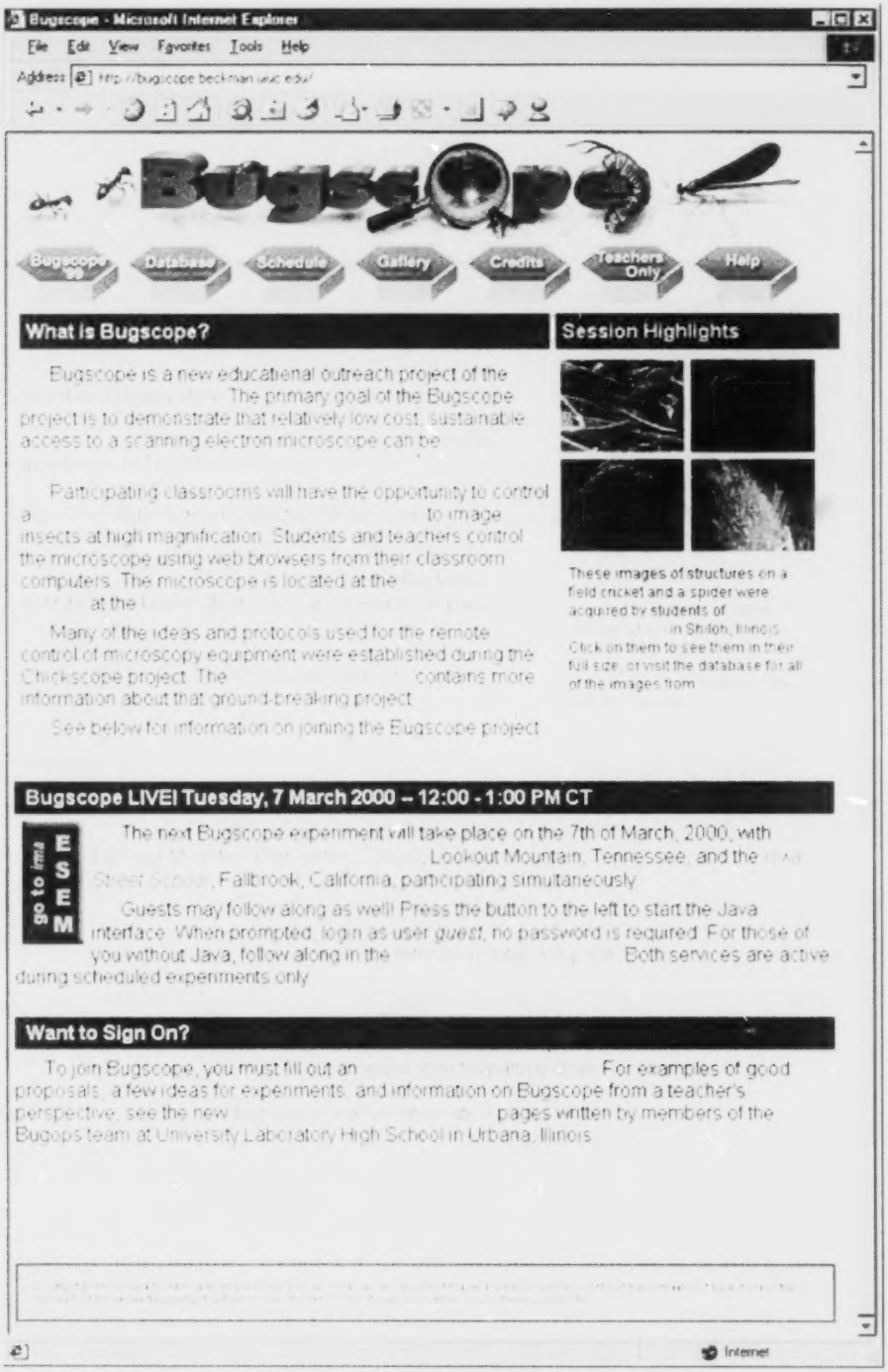
Bugscope - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Address
Bugscope
Database
Schedule
Gallery
Credits
Teachers Only
Help
What is Bugscope?
Session Highlights
Bugscope is a new educational outreach project of the
The primary goal of the Bugscope project is to demonstrate that relatively low cost, sustainable access to a scanning electron microscope can be
Participating classrooms will have the opportunity to control a to image insects at high magnification. Students and teachers control the microscope using web browsers from their classroom computers. The microscope is located at the at the
Many of the ideas and protocols used for the remote control of microscopy equipment were established during the Chickscope project. The contains more information about that ground-breaking project.
See below for information on joining the Bugscope project.
These images of structures on a field cricket and a spider were acquired by students of in Shiloh, Illinois. Click on them to see them in their full size, or visit the database for all of the images from
Bugscope LIVE! Tuesday, 7 March 2000 -- 12:00 - 1:00 PM CT
go to the SEM
The next Bugscope experiment will take place on the 7th of March, 2000, with Lookout Mountain, Tennessee, and the Fallbrook, California, participating simultaneously.
Guests may follow along as well! Press the button to the left to start the Java interface. When prompted, login as user *guest*, no password is required. For those of you without Java, follow along in the Both services are active during scheduled experiments only.
Want to Sign On?
To join Bugscope, you must fill out an For examples of good proposals, a few ideas for experiments, and information on Bugscope from a teacher's perspective, see the new pages written by members of the Bugops team at University Laboratory High School in Urbana, Illinois.
Internet

Figure 1. Bugscope home page.

BEST COPY AVAILABLE

This paper provides an overview and a formative evaluation of the project to assess its ongoing activities. The data collected is from March 1999 to February 2000, the first year of the project, during which 33 schools across the nation were selected to participate.

Relevance to the Special Interest Group on Advanced Technologies for Learning

Science laboratories have existed in the United States since the late 1870s. Linn (1997) provides social contexts of science laboratories in pre-college instruction. In one context, referred to as the partnership period, experts in different fields such as natural science, pedagogy, and technology worked together in the design of laboratory and materials. Partnership period projects focussed on helping "learners become responsible for their own learning rather than presenting information to be observed" (Linn, 1997, p. 408). A partnership approach to science laboratories views students and teachers as part of a community of investigators, as established scientists (Burbules and Linn, 1991). The Bugscope project, which embraces such an approach, presents unique challenges, especially due to the role of remotely participating teachers in their classrooms across the nation. Lessons learned from these challenges will be of interest to the education research community.

This paper, then, will contribute to the Special Interest Group on Advanced Technologies for Learning on the design of new educational technologies that transform educational practice. Bugscope is an emerging educational innovation where K-12 students and teachers carry out their own scientific investigations.

Background

The interest in remote scientific instrumentation projects for K-12 education is growing. President Clinton, in a memorandum to the heads of the executive departments and federal agencies, has set several guidelines for enriching the role of the Internet as a learning and teaching resource (Clinton, 1997). One of the guidelines is to provide students and teachers with access to networked scientific instruments along with an online mentoring support structure to guide scientific inquiry.

Although remote scientific instrumentation is today an exotic and expensive technology for schools, it is clearly becoming part of the daily practice in research and industry (e.g., Kouzes, et al., 1996). This suggests at least two things. First, K-12 students and teachers need to learn more about it because this kind of instrument access and control is becoming an integral part of performing scientific research. Second, as with most technologies, it is likely to become much more commonplace and less costly in the near future. This has happened in the case of electronic mail (email), which is now part of the everyday activity in many schools. The particular instruments and scientific domains may differ, but understanding of the principles underlying this mode of learning through projects like Bugscope is generalizable (Bruce, et al., 1997).

Despite the growing importance of remote instrumentation in science, industry, and medicine, few educational projects have used it for pre-college instruction. Some

examples of remote instrumentation projects are mentioned here (see, also, Morgan, Pardoe, and Smith, 1998, for a review of such projects). For example, the MicroObservatory[4] is a project at the Harvard-Smithsonian Center for Astrophysics where high school students and teachers can control a network of five automated telescopes over the Internet. Another example is Interactive Nano-Visualization in Science and Engineering Education,[5] which provides real-time operation of a scanning probe microscope over the Internet to upper-level high school and first-year college students and teachers. Yet another project called Stardial[6] uses an autonomous astronomical camera on the web to provide authentic problem-solving activities for undergraduate instruction (McCullough and Thakkar, 1997). A very successful project is Hands-On Universe[7] where high school students nationwide can request observations from professional observatories. However, such projects are not generally applicable to classrooms across K-12. In addition, rarely do such projects allow real-time remote access and control capabilities to classrooms across the nation, as does Bugscope.

Previous work

Prior to the Bugscope project, another WWL innovation, the Chickscope project,[8] allowed students and teachers from ten classrooms ranging from kindergarten to high school, including an after-school science club and a home school, to study the 21-day chicken embryology development using a remotely controlled magnetic resonance imaging (MRI) instrument.[9] Using computers in their classrooms with access to the Internet, students and teachers were able to login to the computers at the university, manipulate experimental conditions, and then view resulting MR images of a chicken embryo in real-time. Researchers at the university answered students' questions about the images and related issues. Although the Chickscope project was successful in immersing students and teachers in a scientific community (Bruce, et al., 1997; Mason-Fossum and Thakkar, 1997), the project was not sustainable because of the large number of people and enormous technology resources needed to support a small number of classrooms. For example, the operations team for this project involved intermittent help of at least ten individuals. In addition, over one hour of the instrument time was needed to set up the system for four hours of remote classroom access per day during the project. Since the completion of the Chickscope project, there have been many inquiries from around the world asking if the project would be repeated, requesting access to the resources, and seeking expertise.

As a starting point to address the growing interest in Chickscope, a professional development program for K-12 teachers of mathematics and science from east-central Illinois was developed with support from the Lumpkin Foundation (Potter, 1997) and the Illinois Board of Higher Education (IBHE) (Bruce and Thakkar, 1997). Thirty-two teachers from 15 schools representing kindergarten to high school grade levels

[4] http://mo-www.harvard.edu/MicroObservatory
[5] http://invsee.asu.edu/Invsee/invsee.htm
[6] http://www.astro.uiuc.edu/stardial
[7] http://hou.lbl.gov
[8] http://chickscope.beckman.uiuc.edu
[9] http://chickscope.beckman.uiuc.edu/about/overview

participated in the professional development program, called Illinois Chickscope,[10] for 11 inservice days during the spring, summer, and fall semesters of 1998. Each inservice session included interactive discussions and hands-on and computer-based activities related to chicken embryology, egg mathematics, and MR imaging. Teachers collaborated with preservice teachers, graduate students, and interdisciplinary faculty and researchers from eight university units. The program was successful because it demonstrated that the Chickscope project could be scaled up to a larger community (Bruce, Thakkar, and Hogan, 1999). The IBHE later funded the project for another year (Bruce and Thakkar, 1998). The program demonstrated that although the Chickscope project was not sustained as a remote scientific instrumentation project, it was sustainable through the use of project resources, such as the MRI database, that teachers would use to develop activities for their students. As one special education teacher who taught all subjects to students from 5th to 7th grades said,

> I would rather have the database to use since it would easily fit into my ever changing schedule. Since it is possible for students to virtually hand pick any image possible, having a database of images is just as good and seems more practical than using [an] actual MRI.

Illinois Chickscope did not provide participating teachers and their classrooms access to the remote MRI system. This was because the MRI system was then unavailable, and the resources (people and technology) needed for the project would still be enormous. Indeed, many teachers participating in Illinois Chickscope considered not having the access to the remote MRI system a missing component of the project. As one teacher who taught all subjects to gifted students in 2nd and 3rd grades pointed out,

> I would be disappointed if we won't be able to do some kind of remote instrumentation in the future. That really was the lure and appeal of this project for us. A simulation would be [okay] but it's not really what scientists do. Trying and failing and sometimes succeeding would be far better than walking through images that someone else made.

Hence, the primary goal of Bugscope is to provide sustainable access to remote scientific instrumentation to classrooms nationwide. The lessons learned and experiences gained from Chickscope and Illinois Chickscope were useful in the development of Bugscope.

Bugscope Infrastructure

The unique opportunity that Bugscope provides to students and teachers is possible through a supporting infrastructure of people and technology. Although this is normally available to scientists, it is rarely offered to K-12 classrooms (Potter, et al., 1999).

An example of how a classroom participates using the Bugscope infrastructure follows:

[10] http://www.ed.uiuc.edu/projects/inquiry/chickscope/chickscope

A teacher interested in the project submits via the Bugscope web site a short application with information about herself, her school, and the computer facilities available to her students. Included within the application is a brief project proposal where the teacher describes her interest in Bugscope and specific classroom project plans to use it.

The project team reviews the teacher's application, which is assigned a proposal number. After the teacher application is selected for participation, a time is scheduled for her students to remotely use the microscope for their scientific investigations. Next, the teacher mails an insect specimen. The project's operation team prepares the specimen sent by the teacher and then places it into viewing chamber in the microscope before the session. Prior to the session, the teacher completes an online background form with additional information, such as her experience with microscopy and computers.

Before starting to access the microscope using the username and password assigned to her, the teacher reviews the Help page on the web site to determine the computer/browser requirements for running the microscope. The teacher then tests her computer/browser setup using a simulator (i.e., Bugscope setup tester program) to verify that her setup is capable of running the microscope.

During the teacher's session, the operations team is available to interact with her and her students through a chat program. The images acquired during the session are automatically archived in a database for use by the teacher and her students, who can retrieve the images at any time using their project proposal number.

After the session, the teacher completes an online form to provide feedback about the session. Later, teacher also completes another online form to submit a summary report of her classroom project.

People behind Bugscope

The Bugscope project has no full-time staff. The project is a collaboration of over a dozen faculty, staff, and students at the University of Illinois at Urbana-Champaign and the University Laboratory High School.[11] The project team expertise includes biology, electron microscopy, entomology, imaging, instructional design, remote scientific instrumentation, software engineering, visualization, and web design and development. A critical subgroup of the project is the operations team that supports remote classrooms.

Technology behind Bugscope

There are three components of the technology infrastructure: an environmental scanning electron microscope, the interactive remote microscopy application (*irma*) software to access and control the microscope (Grosser and Kisseberth, 1999), and the project web

[11] The first Bugscope project meeting was held on January 11, 1999. The infrastructure of people and technology for supporting Bugscope was organized at this meeting.

site, with a variety of resources for the classrooms.[12] A session web page for each classroom allows students and teachers to utilize the supporting infrastructure of people and technology for their project.

Environmental scanning electron microscope

Most optical microscopes (what are commonly termed "light microscopes" or "dissecting microscopes") that are available in schools today use a light source to illuminate specimens that are magnified using glass lenses. The highest magnification attainable with any light microscope is approximately 1000x. The highest magnification capability of most classroom light microscopes is more likely to be in the range of 400 to 600x. The typical dissecting microscope magnifies to about 20x. Light microscopes were not intended for three-dimensional imaging, and dissecting microscopes were designed for it but have limited magnification capabilities. In addition, the typical K-12 classroom microscope rarely provides the ability to save an image of the chosen feature or specimen. The environmental scanning electron microscope is capable of imaging at much higher magnification, and provides much better resolution and depth of field than any light microscope.[13] The ESEM has a magnification range from about 17x to over 500,000x.[14] For this project, however, the highest magnification available to students is less than 30,000x. Scientists at the university from several disciplines, such as biology, geology, and materials science, use the ESEM for their research.

Interactive remote microscopy application software

The *irma* software is a web based system for remote access and control of the microscope. The main components of the *irma* software are the image observer and the scope controller (see Figure 2).[15] The observer automatically displays the current image that has been acquired by the microscope. Although the observer is primarily a passive application, it has a few controls that students can manipulate. For example, a student can classify an image as a high quality image by clicking on the 'Mark Image' button. The controller provides the capability to manipulate parameters of the microscope, such as magnification, focus, and contrast, remotely. The *irma* software also allows several classrooms to simultaneously and independently access and control the microscope. Thus, there can be any number of observers and several controllers active at one time.

---

[12] The microscope was delivered to the university on January 6, 1999, and it was installed on January 15. The project web site was accessible starting January 25. The first teacher application was received on January 31 from a school in Nashville, Tennessee. The *irma* software, specifically developed for the project, tested the remote access and control of the microscope on March 1. The first classroom session occurred on March 12 from a high school in Champaign.

[13] The impact of electron microscopy on biological sciences has been documented (e.g., Rasmussen, 1997).

[14] The ESEM used by the Bugscope project is manufactured by the FEI Company. The ESEM model is the field emission Philips XL30, and costs about $600,000.00.

[15] Both the observer and the controller are written in Java programming language to allow for multiple platform capability. For classrooms with computers that cannot use the *irma* software for a variety of reasons, such as firewall or web filtering software, an alternative Common Gateway Interface (CGI) version is made available.

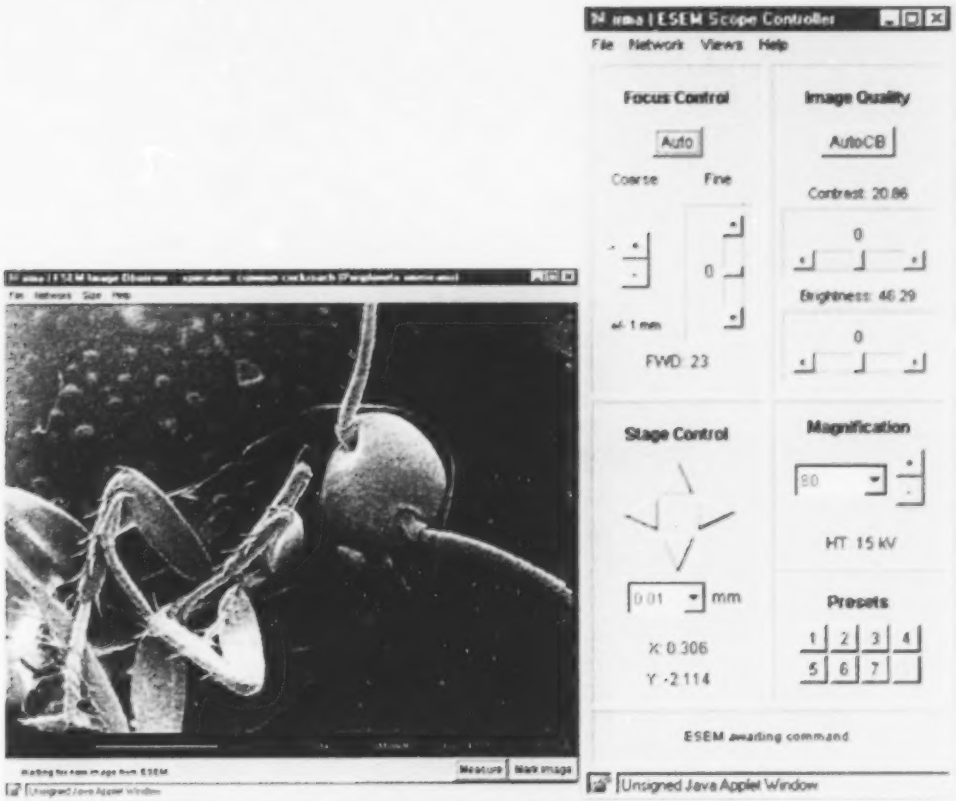

Figure 2. Image Observer and Scope Controller.

Bugscope web site

The Bugscope project web site has been designed to provide teachers (and their students) easy access to a variety of resources.[16] Among these are the teacher application, teacher information, classroom session information, and image database.

Teacher application. Teachers interested in participating in the project submit their applications online with information about themselves, their school, and computer facilities available to them.[17] A critical component of the application is the project proposal where the teachers describe their interest in Bugscope and specific classroom project plans.[18]

Teacher information. A resource web page has been developed to assist teachers in submitting their applications, as well as in planning their classroom sessions. This page includes information related to arthropod-related activities and curricular materials,

[16] The web site gets an average of over 200 access requests per day. There have been over 70,000 such requests during the first year of the project.
[17] Over 100 teacher applications have been received from across the nation since the project started.
[18] Teachers also submit information about their local newspaper, which is later contacted by a publicist to generate an interest within the community about the project.

BEST COPY AVAILABLE

specimen preparation guidelines, proposal guidelines, and model proposals for different grade levels.

Classroom session information.

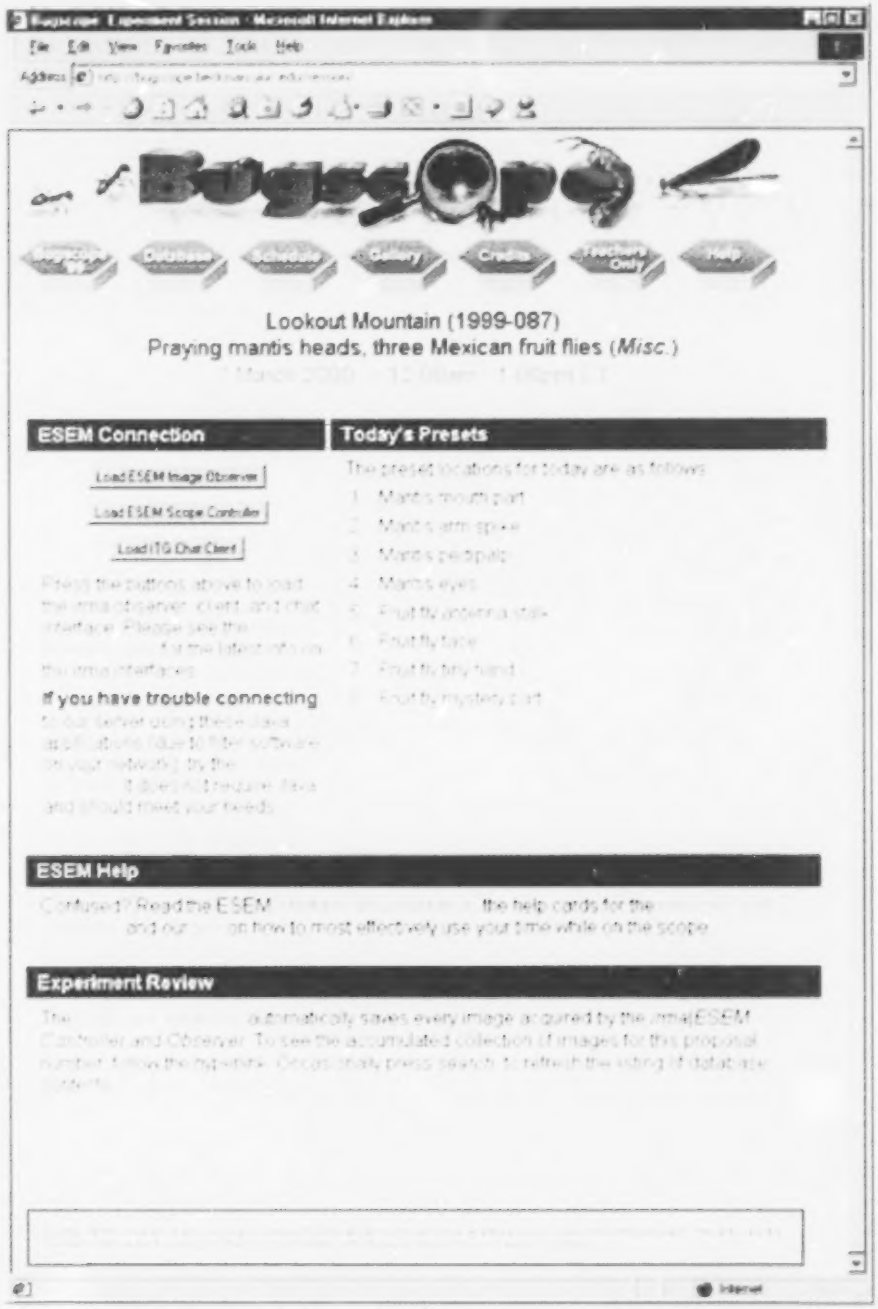

Figure 3. Session information for a classroom (from Tennessee).

BEST COPY AVAILABLE

To give a scheduled classroom access and control of the microscope, a web page specific to their session is created (see Figure 3). The session page provides students and teachers a straightforward approach to running the microscope using the controller and the observer. A chat program may also be initiated to allow for communication between the classroom and the operations team. The session page lists preset stage and magnification positions on the specimen (e.g., praying mantis) submitted by a classroom from Tennessee, for instance. The presets, which are chosen by the operations team, have proven to be helpful to students at all levels in getting started with their sessions. A preset is intended to help students explore a particular feature of their insect specimen. Teachers often request preset features that they would like their students to study or start with. The session page also provides pointers to appropriate help documentation.

Database.

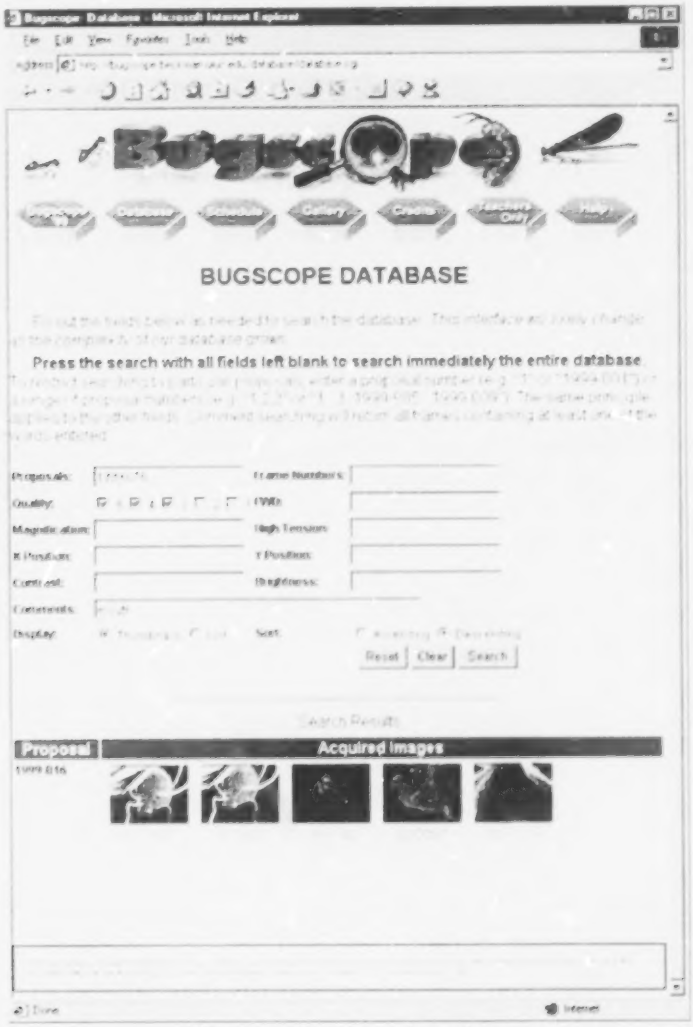

Figure 4. Database interface.

BEST COPY AVAILABLE

All of the images acquired by the classrooms are automatically stored in a database. These images are immediately accessible to the classrooms, as well as to anyone interested in the sessions, through the database interface (see Figure 4). The images are stored with associated acquisition parameters, such as magnification, along with any annotations or comments made by the students and teachers about their acquired images.

In order to achieve scalability and sustainability for the Bugscope project, it has been necessary to automate many project administration tasks, such as the teacher application review. For example, once a teacher submits an online application through the web site, a proposal number (e.g., 1999-016) is automatically assigned to the application. The application is immediately archived into a database on the web site and made available to the project team for critique. A team member can also review the critiques submitted by others for a given application. Teacher applications, especially the project proposals, are rated on a 5-point Likert scale in terms of their overall quality, scientific interest, innovation, suitable grade level, and uniqueness. In addition, a team member critiquing applications can also write comments for a given application. The critiques by team members on an application are automatically synthesized, and the results are immediately available. Without such automation capabilities, it would be difficult to sustain the project in the long term.

Formative Evaluation

> Microscopy is always a favorite unit among my students. There is one page in our text that discusses transmission and scanning electron microscopes. It is quite a forgettable page. However, after Bugscope, I do not think it is an exaggeration to say that my students have a profound understanding of a scanning electron microscope and that they will remember this day for the rest of their lives.
>
> Elementary School Teacher (5th grade)

The overall goal of the evaluation is to develop an understanding of how relatively low cost sustainable access to the microscope can be achieved. As the project currently has K-12 classrooms participating from across the nation, it is critical to evaluate what works and why as the project continues to grow and develop further. Specific questions include: How are teachers integrating Bugscope into their curriculum? How useful is Bugscope as an educational innovation to examine high magnification images of insects and other arthropods? How are classrooms using the remote access to scientific instrumentation? How sustainable is Bugscope over long periods of time?

Data collection

In order for teachers to provide useful information about the project, a three-part online teacher survey mechanism was developed for data collection.[19] The surveys included open-ended, multiple-choice, and Likert scale questions.[20]

---

[19] Appropriate consent from the Institutional Review Board and the Office of School-University Research Relations at the university was obtained before the start of the project.

Background

The first survey was organized to get additional background information about the teacher beyond what was asked in the application. Teachers were asked questions such as how much they knew about insects and other arthropods, what kind of microscopes they had used in the past with their students, and how comfortable they were in working with computers. Teachers were to complete this survey prior to their session.

Implementation

The second survey was organized to get feedback about the implementation of Bugscope in the classroom. Teachers were asked questions such as how useful was Bugscope to their classrooms, what was their overall impression, and were the presets helpful in directing their students' inquiry during the sessions. Teachers were to complete this survey following their session.

Impact

The third survey was organized to get a summary report of the impact of the project in the classroom. Teachers were asked questions such as were they able to accomplish their project objectives, what their students learned that they could not have learned without participating in Bugscope, and what suggestions they had for improvements to the image database. Teachers were to complete this survey within a week or two after their session.

In addition to the surveys, a variety of online data was collected. This included electronic interactions, image acquisitions, and session logs. For instance, for each classroom session, the operations team filled out a session log. A session log would record the opinion of the operations team regarding how the classroom used the microscope.

Background

Thirty-six teachers (28 females, 8 males) were selected to participate during the first year of the project. Twenty-nine teachers (80%) submitted all three surveys. Two teachers submitted the first and the second surveys. Three teachers submitted the first survey. Only two teachers did not submit any of the three surveys. Based on the survey data, this section provides background information about the project participants-schools, teachers, and students.[21]

---

[20] The surveys went through two or three revisions. A few teachers who participated in the project were consulted during these revisions. Thus, there was some difference in the content and format of the initial versions of the surveys that the first few teachers completed when the project started than the final versions of the surveys that most of the teachers completed. Only the final versions of the surveys were made available online.

[21] Sometimes responses by teachers to certain questions were surprising, as the responses were contrary to their overall feedback. Thus, it is possible that some teachers were not always attentive when responding to the surveys.

BEST COPY AVAILABLE

Schools

Teachers represented 33 schools from 18 states in the United States and the US Virgin Islands. Many of the schools were from California (15%) and Illinois (24%). In all, there were fourteen elementary schools, seven middle schools, and seven high schools. In addition, there was a state agency institution for young people representing middle and high school grade levels, a K-12 home school, a K-12 science center, a school representing both elementary and middle grade levels, and a staff development program on technology integration for K-12 teachers.

Schools (N=31) included public schools (77%), private schools (16%), a charter school, and a state agency. School communities (N=31) included urban communities (52%), suburban communities (16%), rural communities (22%), an island community, an exurban community, and a bedroom community.

Teachers

Teachers integrated Bugscope in different subjects across K-12. In the elementary school grades, it was integrated into all subjects as well as computer lab, multiple intelligences and technology, problem-based learning, reading (as a learning disabled resource), and science classes. In the middle school grades, it was integrated into math and computers, math and science, science, and technology integration classes. In the high school grades, it was integrated into advanced placement (AP) biology, biology, forensic microscopy, marine biology, science, and zoology classes. One elementary school teacher used Bugscope during an after-school science enrichment program for exceptional students in elementary and middle school grades, and another teacher used it as part of an inservice session on technology integration.

Prior knowledge about bugs and microscopy. On a 7-point Likert scale ranging from "a lot" (1) to "not much" (7), the teachers (N=33) had some knowledge about insects and other arthropods (3.4 average). The teachers (N=34) also had some knowledge about microscopy (3.6 average) and electron microscopy (4.6 average).

Most of the teachers (79%, N=34) included some form of lessons or units about insects in their curriculum. More than half of the teachers (62%, N=34) included some form of lessons or units about microscopy in their curriculum. Half of the teachers (50%, N=34) included some form of lessons or units about insects and microscopy in their curriculum. Only two teachers did not include any form of lessons or units about insects or microscopy in their curriculum. Most of the teachers (79%, N=34) had previously used microscopes, such as light and dissecting microscopes of different magnification capabilities, with their students. Only one teacher had previously used electron microscopes, such as the transmission electron microscope, with her students. Less than half of the teachers (41%, N=34) planned to collaborate on their project with other teachers at their schools.

Computer usage. On a 7-point Likert scale ranging from "very comfortable" (1) to "very uncomfortable" (7), the teachers (N=34) were somewhat comfortable in working with computers (2.9 average). Most of the teachers (78%, N=32) had a technology coordinator or computer teacher at their schools to ask for help on any computer-related questions.[22] In addition to web browsing, the teachers used computers for HyperText Markup Language (HTML) authoring, image capturing, and image editing. A small number of the teachers (21%, N=28) used computers for image processing.

The majority of the teachers (88%, N=34) assigned their students to use the web for classroom activities. A small number of the teachers (18%, N=34) had prior experience with remote scientific instrumentation projects.

Students

About 661 students (342 females, 319 males) participated in 29 classroom sessions.[23] In addition, some teachers shared their classroom experience with other students and teachers in their schools (e.g., by using a television monitor or a projection system).

To determine the ease of use of the *irma* software, students from three elementary, middle and high school classrooms in Champaign and Urbana performed usability inspection of the software during the course of the first year.[24] Students in these classrooms provided data before and after their sessions through age-appropriate short paper surveys, designed and administered in cooperation with their teachers.[25] To give an example of background of students participating in Bugscope, we present the background of students from one of these classrooms.

Student background in one high school classroom. Sixteen students (9 females, 7 males) from a 9th grade biology classroom provided information about their experiences with bugs, microscopy, and computers, prior to their session.

On a 7-point Likert scale ranging from "a lot" (1) to "not much" (7), the students had some knowledge about bugs (4.3 average) and microscopy (4.8 average). The students did not know much about electron microscopy (6.4 average). The students had used light microscopes to examine plant and animal cells. On a 7-point Likert scale ranging from "very comfortable" (1) to "very uncomfortable" (7), the students were somewhat comfortable in working with computers (2.7 average). All of the students used the web for classroom activities.

---

[22] Some teachers also served as technology coordinators or computer teachers at their schools.

[23] This total includes 14 teachers (11 females, 3 males) who participated as students in one inservice session. Additionally, there were 129 students in two sessions where the teachers did not complete the third survey, which asked for data on student gender distribution.

[24] Innovative guidelines for doing usability research with children during the software development cycle have been proposed by many researchers (e.g., Hanna, et al., 1998).

[25] The applications by these teachers to participate in the Bugscope project had been accepted, prior to contacting them about student evaluations.

Student expectations for participating in the project included "to better understand electron microscopy" and to take "a closer look at the way insects look."

Implementation

This section provides information about the implementation of Bugscope based on the survey responses and session logs. The evaluations by the aforementioned high school students are also presented. In addition, we provide a summary of the high school students in the operations team.

Sessions

Thirty-four sessions were scheduled for 36 teachers from participating schools.[26] The majority of the teachers (93%, N=30) accomplished their proposed project objectives during their session. Only two teachers felt that they had not accomplished their project objectives. On a 7-point Likert scale ranging from "not useful" (1) to "very useful" (7), the majority of the teachers (87%, N=31) thought that their session was very useful (6.1 average). A small number of teachers (13%) thought that their session was sometimes useful.

Session preparation. The majority of the teachers (96%, N=29) used the Bugscope setup tester program simulator to test their computer/browser setup for connecting to the microscope. The majority of the teachers (93%, N=28) felt that the project documentation was helpful in getting their students started. The presets provided by the operations team were considered by all teachers (N=30) to be very helpful in directing the students' inquiry during the sessions. A small number of teachers (21%, N=29) tested connecting to the microscope just before their scheduled time.

Session log. The operations team recorded a log for each session. Of the 34 sessions that were scheduled, 29 sessions (85%) were able to successfully acquire images remotely.[27] A small number of sessions (15%) were scheduled simultaneously as multiple sessions.[28]

---

[26] One middle school had two sessions scheduled simultaneously, with two teachers working together on each session. A team of four teachers from four classrooms (one 7th grade and three 8th grade) had applied to participate the project. The *irma* software at the time, when the school was scheduled to participate, could not accommodate four sessions. Therefore, two sessions were scheduled. Each session had a controller and multiple observers.

[27] Five classrooms were unable to connect due to a variety of technical problems, such as firewall, filtering software, and Internet connectivity problems. The operations team would often acquire images for classrooms when such problems occurred. For instance, one classroom was unable to connect to the microscope using the *irma* software due to filtering software, and the CGI version was not available at the time. The high school students in the operations team acquired images for the class, which were all immediately accessible through the image database. The images acquired were related to questions sent by the teacher regarding what she and her students would like to see on the specimen (caddisfly larva) they had sent (e.g., "Can you show us a close-up of the eyes?"). Also, comments were included in several images to provide the class with additional information on the questions.

[28] Classrooms scheduled as multiple sessions are not aware of existence each other (see Grosser & Kisseberth, 1999, for technical description of the *irma* software operation modes). The exception here was in case of the aforementioned middle school where the teachers and the students worked together during the school's two sessions. Multiple sessions were scheduled at the same time or back-to-back.

The majority of the sessions (86%) used the *irma* software to connect to the microscope. A total of about 4,819 images were acquired during the sessions.[29] At least 30 different types of insects and other arthropods were imaged during the sessions.[30] Most of the teachers (78%, N=36) sent insect specimens for their sessions.[31] The duration of the sessions ranged from less than one hour to less than four hours.

The operations team also rated how the classrooms used the microscope by observing their image acquisitions and their use of controller parameters for these acquisitions. Less than half of the sessions (45%) used the microscope very effectively. About one-fourth of the sessions (24%) used the microscope effectively. A small number of sessions used the microscope somewhat effectively (14%) and not very effectively (17%).

The operations team had electronic interactions (message service and chat program) with students and teachers in over half of the sessions (59%). The majority of the sessions (87%, N=8), where students and teachers interacted with the operations team using the chat program, the microscope was used very effectively or effectively.

With over one-third of the scheduled sessions (35%, N=34), the operations team communicated by telephone with teachers or technology coordinators to assist on a variety of technical questions (e.g., filtering software). While there was only one hardware related (i.e., microscope related) crash during the sessions, about one-third of the sessions (34%, N=29) had minor software related problems (e.g., server running chat program crash) that were quickly resolved by the operations team.

Usability inspection by students in one high school classroom

Students from the high school classroom mentioned previously performed usability inspection of the *irma* software interface to determine its ease of use by completing a survey after their session.

The classroom teacher, who had integrated Bugscope into her biology curriculum, sent several water bugs to the operations team. The teacher wanted her students to have a close-up view of the insects through Bugscope. On different 7-point Likert scales such as one ranging from "difficult" (1) to "easy" (7), the students felt that it was easy to control (5.7 average) and observe (5.6 average) through the software interface.

Although the students felt that the design of the software interface was wonderful (6.2 average), they had trouble sometimes in figuring out what they were looking for using interface (4.9 average). In addition, over half of the students (62%) would find themselves in places where they did not know where they were (i.e., these students

[29] The operations team acquired additional 428 images for classrooms that did not connect.
[30] The number of specimens sent by classrooms ranged from two to twenty-nine and a half.
[31] Some teachers were unable to send insect specimens due to time constraints. Often specimens would get damaged in mail. In such cases, the operations team would come up with specimens based on the teacher's application for the specific classroom session.

BEST COPY AVAILABLE

thought they were lost) while using the interface. However, these students were always able to find their way back to familiar places (6.1 average). Also, all students were able to use the presets to find a way back to the familiar places whether they were lost or not.

The students found the buttons on the interface always easy to use (6.1 average), and they found the terminology on the interface always easy to understand (5.8 average). About one-fourth of the students (25%), who had reviewed the help documentation before they started on their session, found the documentation sometimes helpful (5.5 average). But, the majority of the students (87%) found that the documentation always provided instruction and help when they encountered problems (5.8 average). The students offered many suggestions such as making the interface easier as well as faster to use.

Operations team high school students

> I got the scope set up, helped set the presets, started the servers, and [got] everything ready for a class to connect.
>
> High School Student (10th grade)

Since the core members of the operations team that supports remote classrooms are high school students (1 female, 3 males), a summary of their background and operations team activities is presented.[32]

A high school biology faculty, who is a member of the project team, selected the students. The students completed short paper surveys to provide background information before the start of the project and summary about their activities towards the end of the spring semester.

Student background. On a 7-point Likert scale ranging from "a lot" (1) to "not much" (7), the students knew a lot about insects and other arthropods (2.5 average) and had some knowledge about microscopy (4.5 average) and electron microscopy (5.0 average). On a 7-point Likert scale ranging from "very comfortable" (1) to "very uncomfortable" (7), the students were very comfortable in working with computers (2.0 average). The students used the web for classroom activities. The students viewed their participation in the operations team as an opportunity to gain research experience, learn about insects and microscopy, and work with leading-edge technology.

Student activities. The students performed a variety of tasks, such as identification and preparation of specimens, operation of the microscope, setup for remote classroom sessions, and content development for the web site.[33] The students would meet with other members of the operations team, such as the electron microscopist, and receive appropriate training for one hour a week. Over half of the 30 one-hour sessions (63%)

---

[32] As of the fall 1999 semester, only one of the four students is a regular member of the operations team. Two students who were in 12th grade graduated at the end of spring semester. The other two were in 10th grade. One of them did not plan to continue. An undergraduate student in entomology has the joined the operations team since the beginning of the fall semester.

[33] The first training session for the students occurred on January 22. The last occurred on May 28.

during the spring semester were dedicated to specific training activities, such as taking low magnification images of the specimens sent by schools using a dissecting microscope. The remaining sessions were devoted to performing specific tasks in support of the classrooms that were scheduled to participate.

According to the students, the most important benefits of being part of the team included operating the microscope, learning to work in a group, and getting exposure to electron microscopy (as a possible career choice!). The students felt that Bugscope enhanced a typical high school biology curriculum. As one of the 12th grade students commented,

> Bugscope opens up whole new avenues of study for students studying insects. We could study minute structures in exquisite detail and [hypothesize] why those structures look the way they do.

A sample scenario

To illustrate how classrooms participated in the project, we provide a typical scenario of one high school teacher's implementation of Bugscope in the classroom.[34]

Classroom project proposal

The biology teacher at a public high school in a rural community in Arkansas wanted her students to do science by utilizing technology to better understand the relationship between the two. The teacher then submitted a classroom project proposal related to a water quality project that her 10th grade biology students were planning to undertake.

> We will be doing chemical analysis on local water sources. We would like to participate in the Bugscope project so that we can view [the] macroinvertebrates that will be utilized as indicator species for Ozark water quality.[35] One of our major objectives is to introduce students to as much technology in our science classes as possible. The opportunity to participate in the Bugscope [project] should fulfill this objective and will also increase interest in the environmental issues that we will be studying. We are in a rural agricultural area with concerns of chicken, hog and cattle operations causing runoff pollution. This will be one more way to utilize technology to make local science relevant to our students.

Teacher background. Prior to participating in Bugscope, the teacher had some knowledge about insects, microscopy, and electron microscopy. The teacher has included some form of lessons or units about insects and microscopy in her curriculum. The teacher has used both light and dissecting microscopes with her students previously. The teacher was also somewhat comfortable in working with computers. The teacher assigned her students to use the web for classroom activities.

---

[34] This school session was selected as an example because it occurred around the mid-point of the first year.
[35] The Ozark environment refers to forested upland region found mostly in Arkansas and Missouri.

Implementation

Session preparation. After the teacher's application was accepted, she sent five insect specimens, which included a water bug, a roach and a spider, from the local water area that her students wanted to study. The operations team set eight presets on these specimens for the students to begin their explorations. One of the presets was the roach antenna, for instance, and another was the head of water bug. In addition, one of the presets was a mystery for students to identify. Before the students gained access and control of the microscope, the teacher had already verified that the computer/browser setup in the school computer laboratory qualified for connecting to it. The laboratory had thirty computers (all Pentium-equipped PC with Internet Explorer and Netscape Navigator 4.0 or higher browsers) connected to the Internet.

However, due to the last minute school 10th grade testing plans, the students were unable to participate. The teacher then invited her eight 12th grade students from the advanced biology (College Biology) class to participate. The 12th grade students (4 females, 4 males) were also conducting water testing and had been identifying macroinvertebrate indicators. Hence, the project proposal was relevant to these students as well. Prior to the start of the session, these students had looked at electron microscopy pictures.

Session. Since there were only eight students, the teacher grouped the students on different computers in the laboratory such that one student controlled the microscope, one student used email, and one student was using the chat to interact with the operations team. Eventually all students got an opportunity to control the microscope. According to the teacher,

> The session was very successful, [and] the students were very motivated and excited. We will follow up this activity with looking at EM [electron microscopy] pictures of cells/organelles. We discussed the images as the session proceeded -- we emailed and chatted with Bugscope technicians as the session progressed -- the students were very intrigued with this aspect of the technology utilization.

The students acquired over 200 images of their specimens. The image in Figure 5 is a good example of the images acquired by the students. According to the electron microscopist, the students used the roach antenna preset and the controller parameters to locate the roach's face by first moving along to an area of interest to them, second magnifying that area, then focusing, and finally adjusting the contrast and brightness parameters. This was apparent to the electron microscopist, as the image is a close-up of the "ball" part of the "ball and socket" mechanism through which the antenna is attached to the head of the roach. The students had magnified the most distal portion of the roach's antenna.

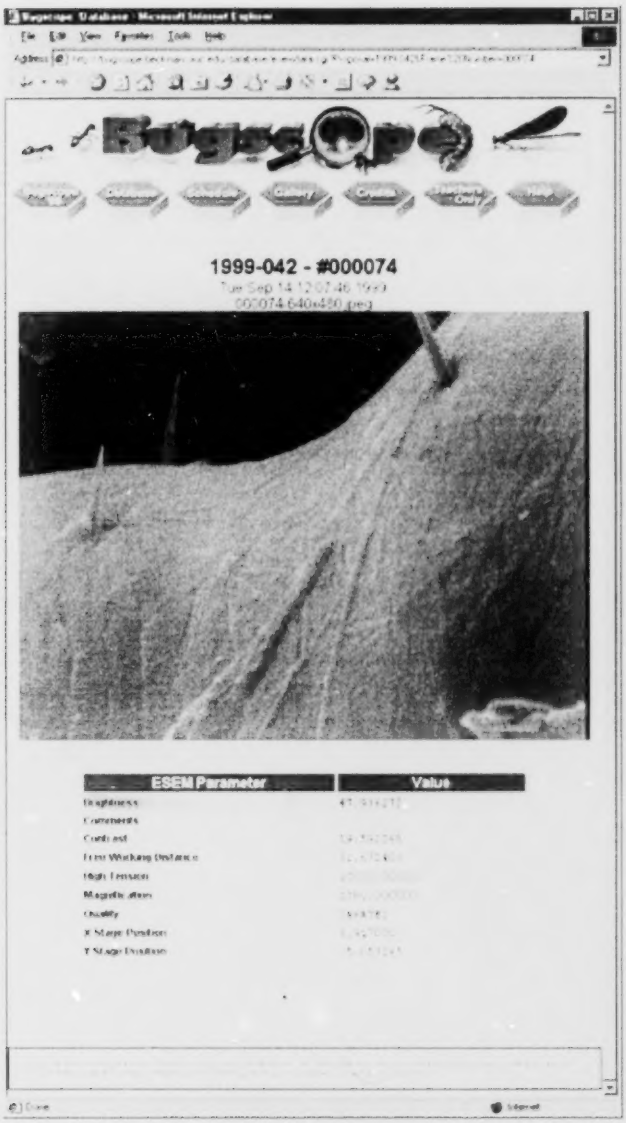

Figure 5. Roach's antenna.

The students also marked images of special interest, such as spider images as the 10th grade students were studying spiders. The teacher felt that these images will enhance her curriculum by using technology to make local science relevant to the students.

> Utilization of the images derived during [the] Bugscope project will allow me to enhance my curriculum with material that will be relevant to the Ozark environment. The images will enhance my water project by allowing me to have specific examples and images from our area. I expect the interest that was generated in my classroom initially to continue the whole year.

BEST COPY AVAILABLE

The students used the microscope very effectively, and the teacher reported that the session was very useful to her students since it illustrated the complexity of microscopic structures. The teacher believed she accomplished her project objectives, although with a different group of students. The session also raised issues and questions that will allow the teacher to continue to engage her students in scientific inquiry.

> The activity really demonstrated to me that the power of the Internet and technology in motivating my students. There were many questions and side issues related to the activity that it will take most of the year to address them all. I found that all of my classes can benefit by the experience as we will access the images during computer labs and discuss them and incorporate them into the lessons.

Impact

The Bugscope project, like the Chickscope project previously, has demonstrated that it is feasible to provide remote access to scientific instruments to K-12 classrooms. However, unlike the Chickscope project, the Bugscope project continues to grow. In this section, we address issues based on the aforementioned questions for a formative evaluation of the project in order to understand its current impact and to guide further development.

Integrating Bugscope into the curriculum

Teachers integrated the Bugscope project to enhance their curriculum across K-12 in different subjects in a variety of ways. The majority of the teachers have said that they accomplished their classroom project objectives. Some examples of how teachers incorporated the project into their curriculum are presented.

An example of elementary school curriculum integration. A teacher who taught in a 1st grade elementary school classroom in a rural community in Massachusetts was interested in finding how Bugscope complemented the project on insects she did with her students.

> At the beginning of each year I complete a six to seven week project on insects with my first grade students. We do some field observations at school and at the local Audobon Sanctuary. Identification of insects and knowledge of body parts, life stages and habitats are the main areas, which are explored in this unit. We have created our own imaginary insects using plaster. The children then gave them their own names and described body parts, habitat and food sources. I'd be interested in how you see [the Bugscope] project complimenting [sic] what we do. Is it applicable to first grade children?

The teacher sent over twenty-nine insect specimens (the most so far) after her application was accepted. Since her 17 students (10 females, 7 males) were young, the teacher organized the session carefully.

> I set up the project so I was the one who manipulated the scope. The children sat and observed the images on either three computers around the room or on an

> overhead TV monitor hooked up to my computer. They gave me suggestions as to what body parts to focus on and what magnification they wanted to see. I did this due to their young age. I had shown them [Bugscope] web site the day before and shared the images from the gallery. I talked briefly about the microscope but for most this was too technical. We did get out a map to see how far it was to Illinois and decided it was close to 1000 miles away; including the ferry ride from the island. I also sent home a notice to parents so they could talk with their kids about it at home. The children were quite impressed with the images we saw and saved. In the afternoon pairs of children who were interested used the controls on the computer. It was easy for them to use with a little guidance.
>
> [Bugscope] gives a whole new dimension to the children's understanding of key objectives. It also connects technology in a real life way to other areas of study. It can be challenging to tie in technology to classroom studies in new and different ways. This project certainly meets this goal.

The teacher's careful organization included giving her students a concept of the remote distance of the microscope, and involving the entire class during the session. In the beginning the teacher was not sure if Bugscope would be applicable to her 1st grade class, but towards the end found that it connected very well to the project on insects that the students were doing.

An example of middle school curriculum integration. A math and computer teacher in an urban community in Illinois wanted to expose her students to new technologies. Bugscope was ideally suited to her curriculum plans.

> I want very badly to expose my students, who are all African American and who come from impoverished backgrounds, to the new world of the next millenium. My students don't have computers at home and I want them to be able to explore as much as they can in the time that they are with me. I happen to be fascinated with bugs and all children are and I thought that this would be a great project to involve them in and myself.

After the teacher's application was accepted, she sent five cockroaches for her students to study. Bugscope inspired the teacher to develop math activities for her 29 students (14 females, 15 males) from 6th and 8th grades.

> I made some math problems from the roach facts about gestation, etc. It made my curriculum more exciting for the students and it gave us an opportunity to share an experience with one another as a team, to bond under one mission that none of us (even the teacher) had experienced. My students felt very special.

An example of high school curriculum integration. A science research and AP biology teacher in an exurban community in New York wanted to immerse her students in designing an experiment involving the woolly adelgid.

> First and second year students in [the high school's] three year science research course will investigate the impact of the woolly adelgid (Adelges tsugae), an aphid-like insect, on several species of hemlock (Tsuga spp.) --- with a specific focus on the effectiveness of integrated pest management (IPM) approaches in slowing hemlock mortality rate. Students will use Dialog, an online international database, to access relevant journal articles. Based on his/her reading, each student will design an experiment involving the use of the ESEM. One experiment will be chosen and carried out, hopefully in conjunction with a scientist/mentor in the field.

The teacher sent more than five insect specimens, including woolly adelgids. The teacher reorganized her session to include seniors. She wanted the science research students to focus their study on the woolly adelgid, and the AP biology students to focus on electron microscopy. The teacher involved 27 students (13 females, 14 males) from 10th to 12th grades in the session after they had done background preparation for it, such as reading articles related to their project, collecting samples, and contacting scientists.

> [Bugscope] provides a very powerful model to science research students who are embarking on carrying out long term (3 year) individual original research projects. To participate in a project from start to possible finish in a short period of time gives them an idea of what's involved and the experience of knowing that it is doable.
>
> For the AP [biology] students, it lets them see first hand what electron microscopes are all about...especially the new and improved ESEM, which isn't even in their textbook yet.

Science research curriculum programs are designed to teach students how to conduct scientific research, and to provide them with opportunities to work with scientists.

In addition to integrating Bugscope, how teachers integrated the project content (i.e., entomology and microscopy) into their curriculum may have also played an important role in generating interest about the project. For instance, most of the teachers (77%, N=22) in classrooms where students used the microscope very effectively or effectively included lessons or units about insects in their curriculum. Half of these teachers (50%, N=22) included lessons or units about microscopy in their curriculum, while most of the teachers (77%, N=22) previously used microscopes with their students. About one-third of the teachers (36%, N= 22) included lessons or units about insects and microscopy in their curriculum.

It is also important to point out that Bugscope may have been just one small component in the overall curriculum plans by teachers. For example, Bugscope was integrated into an entomology unit for 51 3rd grade students (23 females, 28 males) at an elementary school in a rural community in Rhode Island (see Figure 6).[36]

---

[36] http://www.chariho.k12.ri.us/hv/bugshome.html

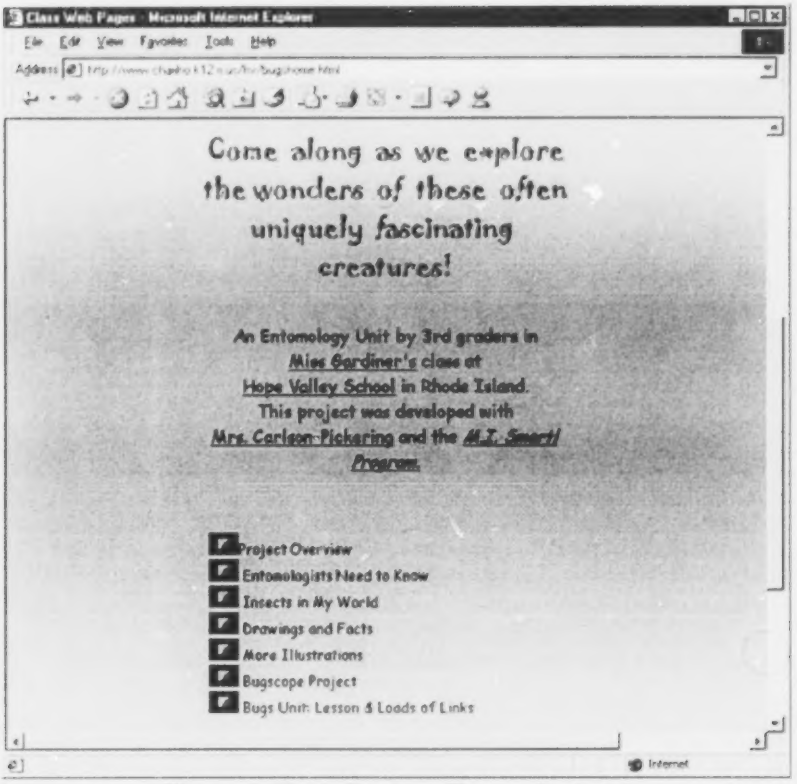
Class Web Pages - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Address
Come along as we explore the wonders of these often uniquely fascinating creatures!
An Entomology Unit by 3rd graders in Miss Gardiner's class at Hope Valley School in Rhode Island.
This project was developed with Mrs. Carlson-Pickering and the M.I. Smart! Program.
Project Overview
Entomologists Need to Know
Insects in My World
Drawings and Facts
More Illustrations
Bugscope Project
Bugs Unit: Lesson & Loads of Links
Internet

Figure 6. "Let's Become Entomologists."

The entomology unit focussed on different aspects about insects. One instructional objective of the unit was to provide students with tools used by entomologists, such as a microscope, to carry out scientific investigations on insects of their choice. This was the unit's connection to Bugscope. The students learned new terms during their session, such as deer tick's proboscis and electron microscope. According to the teacher,

> They learned about the fine details of an invertebrate that allow it to live and function in a world that was previously foreign to my students. It opened the door to scientific pathways they hadn't even dreamed of before. They became absolutely glued to the screen viewing these "unknown" images through the eyes of a scientist. This project stirred curiosity that led to wonderful observation, questioning techniques and thinking strategies. It also provided them the opportunity to feel like they were real scientists with real work to do.

Usefulness of Bugscope as an educational innovation

Bugscope allows students to examine high magnification images of their specimens. However, a concern was whether the project was useful to students and teachers. For instance, were students learning things that they would not have learned without participating in the project. Some examples from the elementary, middle, and high schools previously mentioned are presented to indicate the usefulness of Bugscope.

BEST COPY AVAILABLE

Usefulness of Bugscope to students and teachers at an elementary school. The teacher from an elementary school in Massachusetts was pleased about the experiences her 1st grade students had in learning about different characteristics of their insects by understanding how the parts of these insects are connected. As the teacher said,

> It really showed a compound eye, which is a difficult concept for them to understand. They were amazed by the segmentation and hairs on the insect bodies. I think they will have a much clearer sense of how the parts are all connected through seeing actual objects rather than pictures in books and taking my word for it.

The class took a series of images about the ant's head focusing on its compound eye. The image in Figure 7 magnifies the ant's mouth. The entire series of the images taken by the class demonstrated (to the electron microscopist) an intelligent use of the microscope.

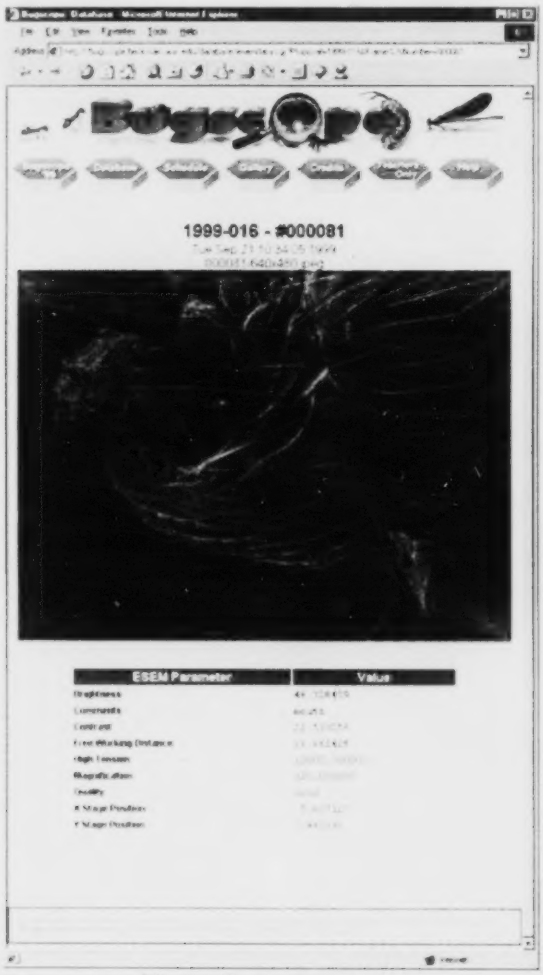

Figure 7. Ant's mouth.

BEST COPY AVAILABLE

An important project benefit to the teacher has been a new confidence, which increases likelihood of her applying to become involved in projects that she would have not considered otherwise. As pointed out by the teacher,

> [It] will give me different reference points to use when talking with the class about the different characteristics of insects. I may be more inclined to apply to more projects of various types, which might have seemed overwhelming before.

Usefulness of Bugscope to students and teachers at a middle school. The math and computer teacher from a middle school in Illinois seemed delighted by what her students learned by examining their roach specimens up close. It was interesting to learn about the efforts by the students to do research about their insects for a science activity in a math class. Bugscope motivated these students in carrying out their own scientific investigations and made the teacher's curriculum more personally meaningful.

> The beauty of things close up. How intricate even the smallest of bugs is. How an animal's body is built for its survival, etc. We were motivated to research facts about roaches that blew us away before we even started to view the bug.

Usefulness of Bugscope to students and teachers at a high school. The science research and AP biology teacher from a high school in New York thought of the woolly adelgid project proposal, specifically for Bugscope, so that her students could get the experience in doing a research project in a short period of time from start to finish.

> There's no way to replace the experience of picking out tiny little orange nymphs from many hemlock branches, sending them through the mail and then seeing them magnified 25,000 times on a giant screen! And to be able to manipulate the samples, photograph them, have the digitized images available to anyone on the Internet, and possibly characterize something no one else has ever done...is a bit mind boggling!
>
> There's no way we could have done this without Bugscope...nor would I have ever conceived of the hemlock woolly adelgid project!

An important project benefit to the teacher was "being able to operate the ESEM remotely." The teacher planned to use the woolly adelgid images acquired by students in her biology classes, and work with an entomologist to review these images.

> We have/are continuing to create montages of some of the images by importing them into Adobe Photoshop.
>
> Our goal is to characterize the pore plates on the dorsal surface of the adelgid. We really only did a thorough scan of one or two adelgids but it should give us some information. We will work in association with an entomologist in doing this work.

BEST COPY AVAILABLE

Remote access to scientific instrumentation

For school classrooms, remote access to scientific instrumentation is not an everyday activity. Additionally, teachers, or more specifically classrooms, rarely have access to a supporting infrastructure of people and technology for their class projects, as they had with the Bugscope project. Although only a small number of teachers who participated in Bugscope had previous experiences with remote scientific instrumentation projects, the majority of the classrooms were able to connect to the microscope to acquire images, and the majority of the teachers considered their session to be very useful. Most of the sessions used the microscope very effectively or effectively. Two issues emerge from the remote access to scientific instrumentation by classrooms: session organization and communication.

Session organization. It seems that how teachers prepared for and implemented their sessions related to how their students used the microscope. For instance, while the majority of the teachers used a simulator to verify that their computer/browser was capable of connecting to the microscope, only a small number of teachers actually tested connecting to the microscope just before the scheduled time of their sessions. These teachers may have become more familiar with the project technology, especially the *irma* software, and so may have been able to facilitate their sessions very well. The students in classrooms of these teachers (83%, N=6) used the microscope very effectively.

The organization of the sessions by teachers had three components to a varying degree. First was how teachers introduced the project content and technology to students, prior to the session. Second was how students were involved during image acquisitions (e.g., working individually, in groups, or as a whole class). Third was how discussions took place in classrooms during sessions. For instance, a 5th grade science teacher describes how she organized her session.

> I needed to include 40 students in our session because I teach 2 classes of 20. The students sat on the floor in front of a lenticular screen because I attached LCD projector to my computer. I downloaded the instructions for the ESEM controls and xeroxed the diagram of the controls. We spent three class periods the week of our session preparing. We discussed the purpose of the controls and how to use them.
>
> I divided the students into groups of 5. Each student in the group was given a control as his/her personal responsibility. There was a child in charge of magnification, the stage, focus, contrast, and brightness. During our preparation I gave scenarios, such as: Suppose the image is clear but still difficult to see and it is not on an interesting body part. What control(s) would you choose to use? The groups then discussed their game plan and the student(s) in charge of the controls would have been the one(s) to maneuver the ESEM. It was most fair way to deal with so many children. This did not ensure that every student got to manipulate the ESEM during our session, but since we role played in advance and discussed this problem they handled it rather well. We also discussed download times. By

knowing about this in advance, it helped the students cope with download times, which could be wearisome. Each group had little over 5 minutes at the controls and we switched groups during a download.

There was lively discussion as we acquired images. Most of this discussion centered on the successes of the group at the control for choosing the right controls for better imaging.

This teacher, who was from a lower (i.e., elementary) school in US Virgin Islands, used her class computer (Pentium-equipped PC) with access to the Internet via 56Kbps ISDN connection, which accounted for the delay in image download times. This delay did not seem to have affected the students, as they used the microscope very effectively, due to the careful organization of the session by their teacher which included a detailed preparation on how to use the controller for acquiring images effectively.

Communication. Classroom interactions with the operations team during the sessions also played an important role. Students and teachers from the classrooms that communicated with the operations team using the chat used the microscope very effectively or effectively. The high school biology teacher (referred to in *A sample scenario* section) commented that "incorporating the chat seemed to stimulate even more interest and involvement" from her students. The chat allowed the operations team to guide investigations by students and teachers during sessions. For instance, a member of the operations team (Bugops) guides three students from a private school, which has a small coniferous forest within its campus, in a suburban community in Washington as they identify their insect specimens during the following chat interaction:[37]

Roger>	How do we get the picture to stay on the walking stick?
Alan>	Where is the wasp that we sent in?
Melissa>	Can you present the wasp head?
Bugops>	Ok, first a question for all of you. How many controllers are you running?
Roger>	1
Bugops>	Ok. Now to answer the two questions…
[…]	
Alan>	What are we looking at?
Bugops>	To stay on the walking stick, you should use the "click to center" feature on the observer. That's the easiest. Your second option is to set the distance to be something good corresponding to the magnification on the image controller and use the up/down/right/left arrows. For a high magnification, the image distance should be something like .01mm.
Melissa>	Thank you.
Bugops>	If you want to see the wasp head, we can take you there. But it will take a second or two to find it. You'll have to stop sending commands through the controller and the click-to-center feature.

[37] The names of the students have been changed in the edited chat transcript.

[...]
Bugops> Should we find the wasp head now?
Melissa> Yes.

The teacher involved 17 students (6 females, 11 males) from 4th to 8th grade science classes in Bugscope. The teacher had indicated in his application that his students were very interested in insects, especially in parasitic wasps that they raised the year before, and walking sticks, native to the northwest, that they were raising this year. The teacher indicated that because of Bugscope his students were able to see the fine details in the insects they saw everyday in the school. During the session, in addition to the chat interactions with the operations team, the students were also engaged in discussions in the class. According to the teacher,

> There was lots of discussion during capture. There was not only lots of science discussion but the math skills they used to measure specimens were great.

Sustainability of Bugscope over long periods of time

Teachers nationwide continue to apply to participate in Bugscope from a variety of settings, such as a school classroom, a home school, and an after-school science program. Some issues related to project sustainability that have emerged are presented below.

Bugscope classrooms nationwide. One of the goals from the beginning was to make Bugscope available to over 100 classrooms nationwide in the first year. Although we have received enough teacher applications to easily meet the goal, we have reached only about one-third of the goal because we have not received many project proposals of good quality in these applications, even though detailed project proposal guidelines have been developed for teachers. The project information has been shared on a variety of education web sites (e.g., The Exploratorium's Ten Cool Sites).[38] Additionally, the classroom stories about the project have been covered in newspapers (e.g., The New York Times' Circuits section)[39] and radio programs (e.g., National Public Radio's All Things Considered program).[40] As the project develops, efforts will continue to distribute project information to a wide variety of avenues, such as science teacher workshops and conferences, so that it is more known to teachers nationwide.

Availability of the microscope. Another project goal was to make the microscope available to classrooms once a week for less than three hours. Except for a few exceptions, this goal was achieved. One such exception was scheduling classroom sessions on two days during the week. This was done because we wanted to encourage more classrooms to participate when the project started. Another exception was giving classrooms additional time on the microscope during their sessions, as the students were using the microscope very effectively and the operations team was willing to continue to support these classrooms.

---

[38] http://www.exploratorium.edu/learning_studio/cool/natural_history.html
[39] http://www.nytimes.com/library/tech/99/06/circuits/articles/17bioo.html
[40] http://search.npr.org/cf/cmn/cmnps05fm.cfm?SegID=67550

Minimal staff resources. Yet another project goal was to provide training to a team of high school and undergraduate students to primarily manage the operational aspects of the project to support the remote classrooms and to reduce operational cost. The operations team has successfully managed to support classrooms during the first year. For instance, the operations team needs less than half-hour on the microscope for getting it ready for use by classrooms remotely. The operational cost, which includes personnel support for setup, running, and archiving classroom sessions, comes to be less than $100.00 per classroom. This cost does not include the cost of the microscope or the cost to develop the technology infrastructure to support the project.

Automation of tasks. As mentioned previously, one of the critical aspects of sustaining the project was to automate many tasks, such as project administration and data handling tasks. Administration tasks include reviewing teacher applications and then scheduling sessions when the applications are accepted. Data handling tasks include the storing of images acquired by classrooms such that the images can be accessed at any time by any one. Without automation of such tasks, sustaining the project over long periods of time would require a full-time administrator.

Suggestions from the classrooms

Teachers offered suggestions for improvements on different aspects of the project, including the database, the *irma* software, and the sessions. We have incorporated some of their suggestions as the project has continued to develop during the course of the year. For instance, a team of teachers from a middle school in Illinois suggested after their sessions that the observers should have the capability to mark as well as label images. Such a capability, which has since been incorporated into the observer, would make the students more actively engaged while they observe images that are acquired by their classmates during their sessions.

We are still reviewing some suggestions by teachers. For instance, a teacher from an elementary school in South Carolina, who used Bugscope with her 5th grade students for their unit on insects, suggested that a school or bug name could be used to search the database index rather than the proposal number (as it is currently designed). Such a change would make it easier for students to find images about specific insects after their session. The students in her class marked several images, and they used the microscope very effectively. As the session was very successful, the teacher invited several students from other grades to participate as well.

> This was just too cool to only do with one class! This was such an incredible stretch of technology for this district that I wanted to impact as many students as possible and get the attention of administrators to get them excited enough to further the teachers' learning with technology.

A frequent comment by teachers is to request additional sessions to continue to engage students in doing their investigations. As one high school teacher from Illinois said,

I would like two short sessions in which the students could view the insect and then decide what to study. The images from the first session might cause the students to go off on a different tangent. This is exactly what discoveries do - peak [sic] our interest and cause us to investigate something further.

Conclusions

We consider the Bugscope project to have been successful during its first year of operation. Students and teachers had the opportunity to mail in specimens of insects and other arthropods, and then study the high magnification images of these specimens on the microscope, which they remotely controlled from their school computers at a scheduled date and time. The images they acquired were their own authentic data, including irregularities and surprises. Like scientists, they had to first propose a project to request the use of an expensive scientific instrument. Like scientists, they were responsible for planning an experiment and then making efficient and good use of the time that they were allocated on the instrument to gather data. Like scientists, they had an infrastructure of people and technology to assist them. Bugscope thus served the purpose of stimulating an interest in the scientific research enterprise to students and teachers across the nation.

The conclusions from the project include:

- Students and teachers across K-12 from a variety of educational settings nationwide can effectively access and control the environmental scanning electron microscope remotely from their classrooms to examine high magnification images of their insects and other arthropods.
- Teachers were able to effectively integrate Bugscope to enhance their curriculum in different subjects across K-12 in a variety of ways.
- Bugscope has effectively contributed to the growth of teachers across K-12 in understanding the possibilities of remote scientific instrumentation for learning, teaching, and research.
- A relatively low cost, sustainable access to the microscope to classrooms nationwide is effectively possible, by using high school and undergraduate students to manage the operational aspects of the project and through automation of the project administration and data handling tasks.

Bugscope could possibly serve as an education and training model for other projects that involve remote access to scientific instruments.

The suggestions from the project for outreach to K-12 classrooms include:

- Students and teachers should be encouraged to supply their own materials for carrying out their remote scientific investigations.
- Classrooms could be provided with supporting infrastructure including both people and technology during their scientific investigations.

- Remote scientific instrumentation projects should consider issues relating to usability, scalability, and sustainability at an early stage during the project development.

Future directions

During the first year, only one application was received (and selected) for professional development program for K-12 teachers. The teacher who led the inservice training for a group of 14 teachers (11 females, 3 males) from a public school district in an urban community in Oregon wanted to introduce Bugscope as part of her workshop on technology integration.

> It would be great if, during the inservice, [the teachers] actually had the opportunity to use Bugscope. By actually getting to use Bugscope, I believe that they will be more likely to submit a proposal to use it in their classroom(s).

The lead teacher thought that the Bugscope session was very useful to her inservice teachers, and towards the end of the session, she suggested in the chat with the operations team that there will be "4-5 applications for using Bugscope" from these teachers. Such remote inservice sessions will help to prepare and support teachers in their efforts to explore integration of emerging educational technologies for learning, teaching, and research in their classrooms. Thus, one of the possible future directions ahead for the project may be to encourage and solicit applications for inservice training.

Another possible future direction may be to encourage preservice teacher participation. Only a small number of teachers (15%, N=34) who participated in the project during the first year indicated that they had preservice teachers in their classrooms. Recent reports, such as those from the National Science Foundation (NSF, 1996) and the National Science Board (NSB, 1999) highlight the importance of improving future teacher preparation, especially through the use of information technology (e.g., NSF, 1998). Thus, the project may also have to encourage and solicit applications from preservice teachers, either as part of their undergraduate coursework or classroom student teaching.

We are continuing to assess the overall impact of the Bugscope project. For example, how does Bugscope change the way students and teachers relate to classroom learning? As the project grows and develops further, there will be other directions to pursue. The project will continue to provide students and teachers across the nation with access to an infrastructure of people and technology to carry out their own scientific investigations.

Acknowledgements

The Lumpkin Foundation and the Illinois Consolidated Telephone Company provided funding for Bugscope. The environmental scanning electron microscope was purchased through a Major Research Instrumentation grant from the NSF (9871103) and the Beckman Institute for Advanced Science and Technology. The IBM Shared University Research Program and the Informix Software Innovation Grant Program provided additional support. The NSF Partnership for Advanced Computational Infrastructure

Research Experiences for Undergraduates Program (PACI REU 98004) provided undergraduate student support to contribute in the evaluation of scientific instrumentation applications for research and education.

The Bugscope project would not have been possible without the interest and participation of teachers and students across the nation. We especially thank them for their enthusiasm.

The classroom stories about the project have been featured in newspapers nationwide through the assistance of Deborah Aronson. We thank her for this help. We would like to thank Martin Ceperley, Joseph Sapp, and Philippa Soskin, who were former members of the Bugscope operations team, for their contributions.

References

Bruce, B. C., Carragher, B. O., Damon, B. M., Dawson, M. J., Eurell, J. A., Gregory, C. D., Lauterbur, P. C., Marjanovic, M. M., Mason-Fossum, B., Morris, H. D., Potter, C. S., & Thakkar, U. (1997). Chickscope: An Interactive MRI Classroom Curriculum Innovation for K-12. *Computers and Education Journal, 29*(2), 73-87.

Bruce, B. C., & Thakkar, U. (1997, October). *Inquiry-based Learning and Teaching with Emerging Technologies for K-12 Mathematics and Science Teachers.* Proposal to the State of Illinois Board of Higher Education.

Bruce, B. C., & Thakkar, U. (1998, September). *Inquiry-based Learning and Teaching with Emerging Technologies for K-12 Mathematics and Science Teachers.* Proposal to the State of Illinois Board of Higher Education.

Bruce, B. C., Thakkar, U., & Hogan, M. P. (1999). Inquiry-based Learning and Teaching with New Technologies. *Spectrum: Journal of the Illinois Science Teachers Association, 25*(2), 16-19.

Burbules, N. C., & Linn, M. C. (1991). Science Education and Philosophy of Science: Congruence or Contradiction? *International Journal of Science Education, 13*(3), 227-241.

Carragher, B. O., & Potter, C. S. (1998). *The World Wide Laboratory: Remote and Automated Access to Imaging Instrumentation.* Paper presented at the Workshop on the Impact of Advances in Computing and Communications in Chemical Sciences and Technology, National Research Council, November 1-2, Washington, D.C.

Clinton, W. J. (1997). *Expanding Access to Internet-based Educational Resources for Children, Teachers, and Educators.* Memorandum for the Heads of Executive Departments and Agencies, The White House, Office of the Press Secretary, April 19.

Grosser, B., & Kisseberth, N. (1999). *irma: An Interactive Remote Microscopy Application for WWW-Based Control of an Environmental Scanning Electron Microscope (ESEM).* Technical Report 99-007, Imaging Technology Group, Beckman

 BEST COPY AVAILABLE

Institute for Advanced Science and Technology, University of Illinois at Urbana-Champaign, Urbana, IL.

Hanna, L., Risden, K., Czerwinski, M., & Alexander, K. J. (1998). The Role of Usability Research in Designing Children's Computer Products. In A. Druin (Ed.), *The Design of Children's Technology*, (Chapter 1). San Francisco, CA: Morgan Kaufmann.

Kouzes, R. T., Myers, J. D., & Wulf, W. A. (1996). Collaboratories: Doing Science on the Internet. *Computer, 29*(8), 40-46.

Linn, M. C. (1992). Science Education Reform: Building on the Research Base. *Journal of Research in Science Teaching, 29*(8), 821-840.

Linn, M. C. (1997). The Role of the Laboratory in Science Learning. *The Elementary School Journal, 97*(4), 401-416.

Mason-Fossum, B., & Thakkar, U. (1997). Primary school classroom and Chickscope: Studying the egg in the classroom and using the Internet. *Proceedings of the 3rd Conference on Human Factors and the Web*, Denver, Colorado, June 12.

McCullough, P. R., & Thakkar, U. (1997). Stardial: An autonomous astronomical camera on the World Wide Web. *Publications of the Astronomical Society of the Pacific, 109*, 1264-1268.

Morgan, C., Pardoe, D., & Smith, N. (1998). Toward a Standard for Remote Microscope Control Systems. *Scanning, 20*, 110-116.

National Science Board. (1999). *Preparing Our Children: Math and Science Education in the National Interest*. Arlington, VA: National Science Foundation.

National Science Foundation. (1996). *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology*. Arlington, VA: National Science Foundation.

National Science Foundation. (1998). *Information Technology: Its Impact on Undergraduate Education in Science, Mathematics, Engineering, and Technology*. Arlington, VA: National Science Foundation.

Potter, C. S. (1997, December). *Chickscope@Charleston-Matoon*. Proposal to the Lumpkin Foundation.

Potter, C. S. (1998, December). *Bugscope-99*. Proposal to the Lumpkin Foundation.

Potter, C. S., Carragher, B., Ceperley, M., Conway, C., Grosser, B., Hanlon, J., Hoyer, C., Kisseberth, N., Robinson, S., Sapp, J., Soskin, P., Stone, D., Thakkar, U., & Weber, D. (1999). *Bugscope: A Sustainable Web-Based Telemicroscopy Project for K-12*

Classrooms. Technical Report 99-003, Imaging Technology Group, Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana-Champaign, Urbana, IL.

Rasmussen, N. (1997). *Picture Control: The Electron Microscope and the Transformation of Biology in America, 1940-60*. Stanford, CA: Stanford University Press.

Soloway, E. (1994). Ways of Seeing. *Communications of the ACM*, *37*(2), 15-20.